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THE INSHORE - OFFSHORE LOBSTER ISSUE IN SOUTHWESTERN NOVA SCOTIA

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ABSTRACT

Since its inception in 1971, the fishery for lobster (*Homarus americanus*) in offshore southwestern Nova Scotia and Georges Bank has been a contentious issue with inshore fishermen. Concerns were raised on the impact of the offshore lobster fishery on the broodstock potentially sustaining the inshore population and/or on the removal of the seasonally migratory adult component to the inshore area. This report addresses these concerns, by asking the question: Do catches by the offshore lobster fishery significantly reduce catches by the inshore fishery? This question was divided into six hypotheses, which were examined by fisheries biologists, physical and biological oceanographers at a special workshop held in December 1990. In addition to a literature survey, this forum highlighted the many uncertainties regarding the importance of the interactions between inshore and offshore lobster populations, and allowed the identification of several areas where additional research is required. Current lines of evidence suggest that the offshore fishery has not had any perceptible effects on the inshore fishery thus far, and that the most likely impact would be in the reduction of larvae imports from Browns Bank to the inshore area. The impact of exploitation of lobsters from Georges Bank and the eastern Scotian Shelf on the inshore fishery was deemed likely to be small. However, a better understanding of the importance and of the origin of the lobsters caught in the midshore area is required to determine the relative significance of each segment of the southwestern Nova Scotia lobster fishery.

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RÉSUMÉ

Depuis ses débuts en 1971, la pêche au homard (*Homarus americanus*) dans la zone hauturière du sud ouest de la Nouvelle-Ecosse et sur le Banc Georges est un sujet controversé auprès des pêcheurs cotiers. Plusieurs inquiétudes subsistent quant à l'impact de la pêche hauturière au homard sur le stock reproducteur supportant potentiellement la population cotière et/ou sur la capture de la composante adulte migrant saisonnièrement vers la cote. Le présent rapport s'intéresse à ces problèmes et pose la question: Les captures de homard provenant de la pêche hauturière réduisent-elles de manière significative les captures dans la zone cotière? Cette question fut divisée en 6 hypothèses, qui furent examinées par des biologistes des pêches ainsi que des océanographes physiciens et biologistes lors d'un atelier spécial tenu en décembre 1990. Avec l'apport additionnel d'une revue de littérature, ce forum a souligné les maintes incertitudes quant à l'importance des interactions entre les populations cotières et hauturières de homards, et a permis d'identifier plusieurs secteurs requérant des recherches supplémentaires. Les informations présentement disponibles suggèrent que la pêche hauturière n'a pas eu d'effet perceptible sur la pêche cotière jusqu'à présent, et que l'impact le plus probable serait dans la réduction des apports larvaires du Banc Browns vers la zone cotière. L'impact de l'exploitation du homard sur le Banc Georges et le plateau néo-écossais sur la pêche cotière a été évalué comme étant faible. Cependant, une meilleure connaissance de l'abondance et de l'origine des homards capturés dans la zone mitoyenne est requise pour déterminer l'importance de chacun des segments de population contribuant aux captures de homards dans le sud ouest de la Nouvelle Ecosse.

INTRODUCTION

For two decades in Canada the so-called "inshore - offshore" lobster (*Homarus americanus*) issue has existed. The concern expressed by the inshore fishermen is that the offshore fishery, which began in 1971, has had a negative impact on inshore production. The purpose of this report is to address the question: Do catches by the offshore fishery significantly reduce catches by the inshore fishery?

This question was addressed by a literature review and via a special workshop held in December 1990, to which physical and biological oceanographers working in the area were invited. Drs. G.C. Harding, F.H. Page, P.C. Smith and R.W. Trites generously shared their ideas and data on the sub-

ject and their contribution is acknowledged with thanks. However, since the workshop participants did not reach a consensus on several of the issues at hand, it must be stated that the conclusions of this document are those of the authors alone.

The converse question, *Do catches by the inshore fishery significantly reduce catches by the offshore fishery?*, was not considered because the potential effect on the industry is small. Recent landings from the offshore fishery (LFA 41) are only 7% of that from the inshore fishery between Halifax and Digby (Lobster Fishing Areas 33 and 34; Fig. 1). The offshore fleet also includes fewer participants, 8 vs. 1648 licenses, and about 36 vs. 3000 fishermen.

Six component hypotheses are presented and discussed. Evidence is presented for and against each hypothesis, and a choice is made to accept, reject or suspend judgment in cases with insufficient evidence. Further research topics are recommended.

INSHORE FISHERY

The inshore fishery of Southwestern Nova Scotia (LFA 34; Fig. 1) is the largest and, prior to the large increases in landings during the 1980s, one of the most stable in the Scotia-Fundy Region (S-F). The fishery of the South Shore of Nova Scotia (LFA 33) has historically been less stable than that of Southwestern Nova Scotia. Record low landings in LFA 33 during the mid 1970s have increased 10 fold to record high levels in the 1980s (Fig. 2).

The inshore fleet can fish anywhere inside the offshore line, 50 nautical miles (92 km) from the coast (distance measured from Seal Island, and the actual distance from the coast is up to 65 nautical miles or 120 km). Only in Southwestern Nova Scotia and the Gulf of Maine does the fishery extend beyond 20 km, with the inshore fishery extending to the offshore line. The area between the offshore line and about 35 km from shore is sometimes called the midshore (Fig. 3). German Bank, and Lurcher Shoal occupy large portions of this zone. No lobster fishing has occurred in the Browns Bank Closed Area (LFA 40) since its closure in 1979. Exploitation of the midshore began in the mid 1970s and increased greatly in the 1980s (Miller *et al.* 1987). The midshore fishery is distinct from the nearshore fishery by its recent development and lower exploitation rate that

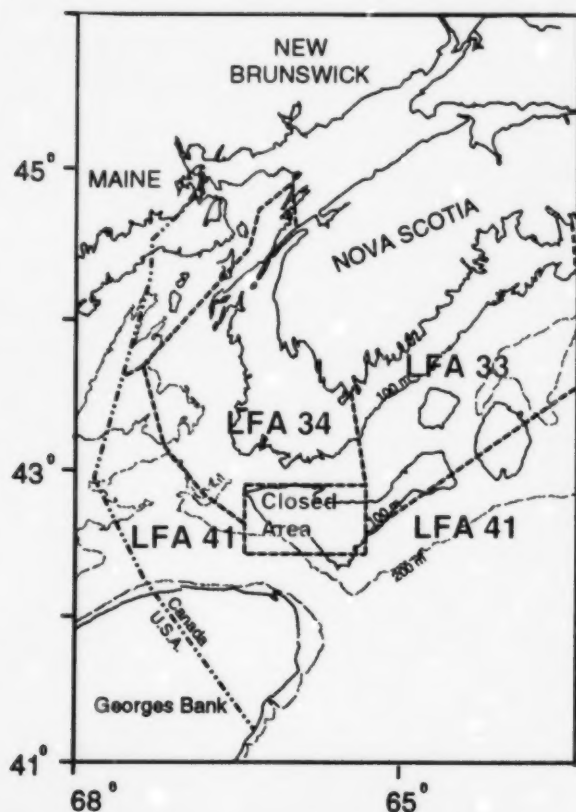


Figure 1. Lobster Fishing Areas (LFA) in southwestern Nova Scotia, showing the Browns Bank closed area and the Canada-U.S.A. Gulf of Maine boundary.



Figure 2. Scotia-Fundy Region lobster landings 1893-1990, and LFA 33, 34 and offshore 1947-1990.

results in mean sizes of 100-125 mm Carapace Length (CL) (Pezzack and Duggan 1983; Stasko and Pye 1980) compared to <90 mm CL in the nearshore (Campbell and Pezzack 1986). The outer portions of the "midshore" abuts the offshore boundary line and inshore fishermen fish side by side with the offshore fleet.

Unlike the Southwestern area, the South Shore fishery does not extend outside the nearshore areas (<20 km off the coast). Trawl surveys report no catches in the midshore area (Fig. 3, 4) and the offshore aggregation is only located along the shelf edge (120-180 km from the coast) between Cape Sable and The Gully east of Sable Island (Pezzack 1987).

For the purposes of this paper the following apply: (i) the management definition of inshore is used, which includes the midshore and nearshore areas (Fig. 3). (ii) The catch of those fishermen who fish along the offshore line is a special case, and is not considered here; (iii) the geographic extent of the inshore is bounded by Digby Neck in the west and Halifax Harbour in the east (Fig. 5) and (iv) the offshore is limited to the eastern Gulf of Maine, eastern Georges Bank and the Scotian Shelf.

HISTORY OF MANAGEMENT AND ADVICE FOR THE OFFSHORE FISHERY

1971 - Offshore lobster licenses were made available to 56 swordfish boats after that fishery was closed due to what was thought to be higher than acceptable mercury levels in the flesh. Inshore and offshore fleets were restricted to inside and outside a line drawn approximately 50 nautical miles (92km) from shore (Wilder 1974).

1974 -Wilder (1974) advised that inshore and offshore lobsters did not mix, based on evidence of size differences and movement of tagged animals.

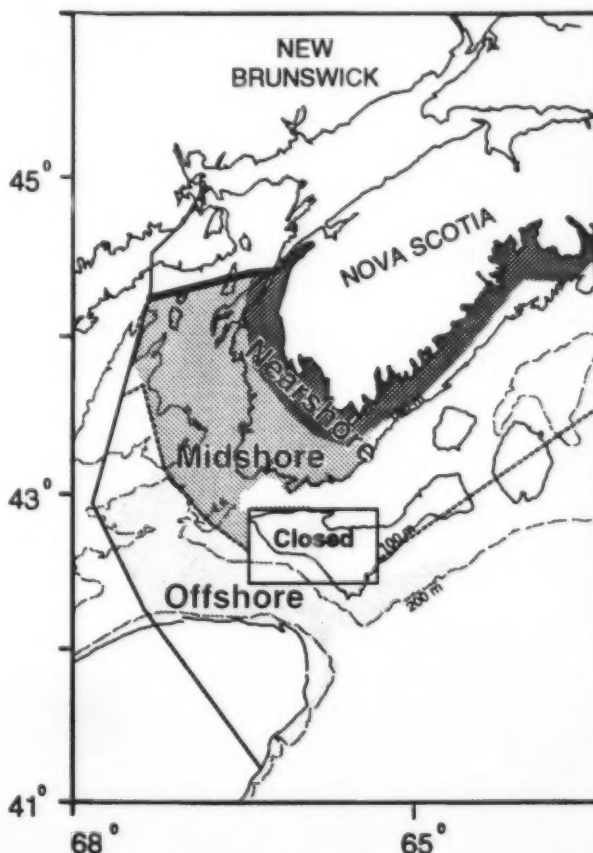


Figure 3. Distribution of lobster fishing grounds, showing areas defined as Offshore, Midshore and Nearshore.

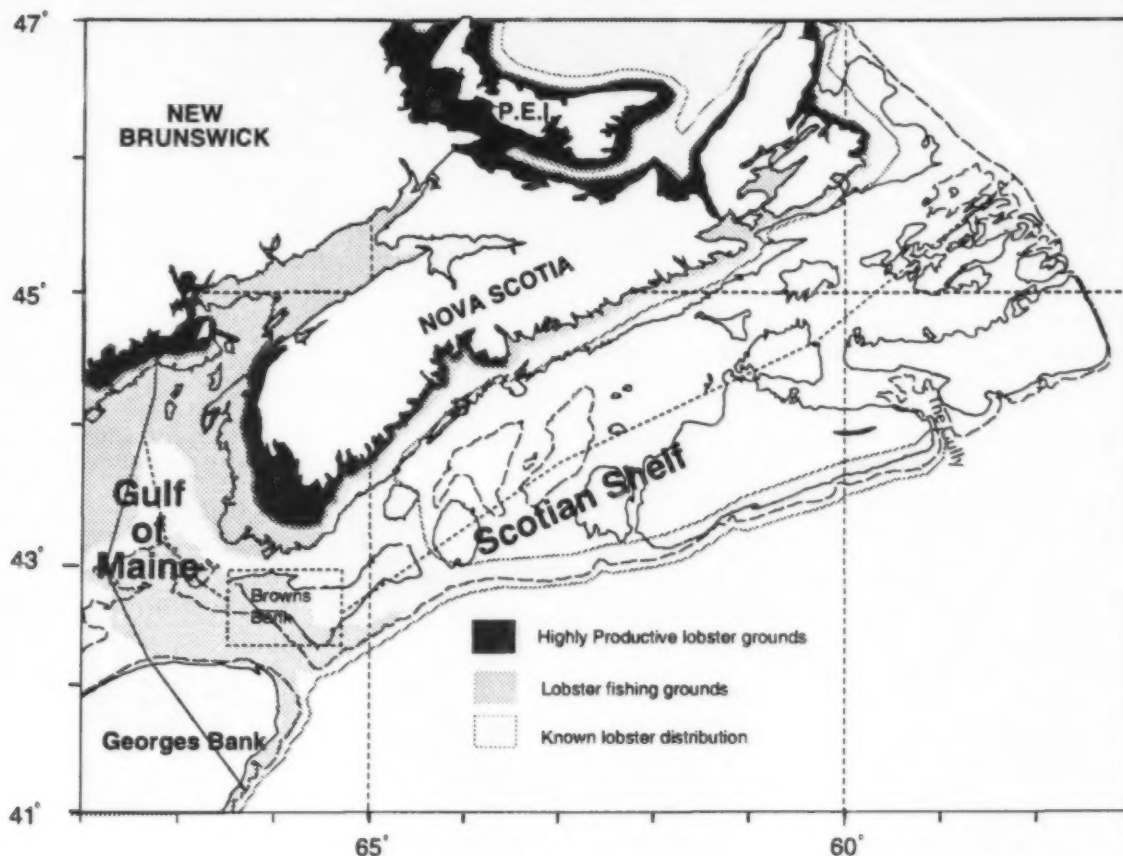


Figure 4. Known lobster distribution on the Scotian Shelf and eastern Gulf of Maine, based on groundfish trawl surveys, and lobster fishery data, showing commercially fished grounds, and highly productive grounds.

1976-7 - Inshore fishermen strongly objected to increased landings and effort by the offshore fleet. Consequently, the offshore fleet was frozen at the existing 8 licenses, and a 9 month season, and 1000 trap/ vessel limit imposed, with a 408t quota in NAFO 4X with 6 vessels given 68 t each. Two vessels were restricted to 5Ze (Georges Bank) and no quota was imposed on catches from Georges because that stock was shared with the unregulated U. S. fishery (Pezzack and Duggan 1985; Stasko 1978).

1978 - Stasko (1978) hypothesized that adult lobsters might migrate from inshore to Browns Bank, and release larvae which drift back inshore. However, after study of larval distribution (Stasko and Gordon 1983) were unable

to determine whether larvae drifted inshore from Browns Bank.

1979 - Browns Bank was closed to lobster fishing to protect a spawning area identified by Stasko (Pezzack and Duggan 1985).

1985 - Following the World Court decision on the Canada/USA boundary in the Gulf of Maine, each of the 8 offshore licenses was given a quota of 90 t, for a TAC of 720 t for 4X and 5Ze combined. The closed season was removed, but the trap limit remained. (Pezzack and Duggan 1988) advised that the trap limit had little conservation value because catches are quota limited, and the limits may increase the cost of fishing.

1987 - Pezzack (1987) advised that the exchange of commercial-sized lobsters between the edge of the Scotian Shelf between La Have and Banquereau Bank and the inshore zone was unlikely.

Jan., 1988 - The minister of DFO announced the addition of four licenses and 360 t of TAC to the offshore.

April, 1988 - The minister of DFO suspended the new licenses after strong objections from inshore lobster fishermen.

April, 1988 - The Scotia-Fundy Lobster Study was initiated because of the above objections as well as recent requests from non-license hold-

ers for more inshore licenses (Anonymous 1989).

1990 - License holders recommended no increase in inshore or offshore licenses (meetings discussing the Scotia-Fundy Lobster Study).

From the inception of the offshore fishery in 1971, inshore lobster fishermen have strongly objected to its existence. Their principal objections relating to biology, "... that offshore stocks contributed to the inshore fishery from inshore movement of lobsters, either in the adult or larval stages ..." (Wilder 1974), have not changed. These concerns were most recently raised during industry consultations on the Scotia-Fundy Lobster Study, and were presented to our workshop by a representative of the

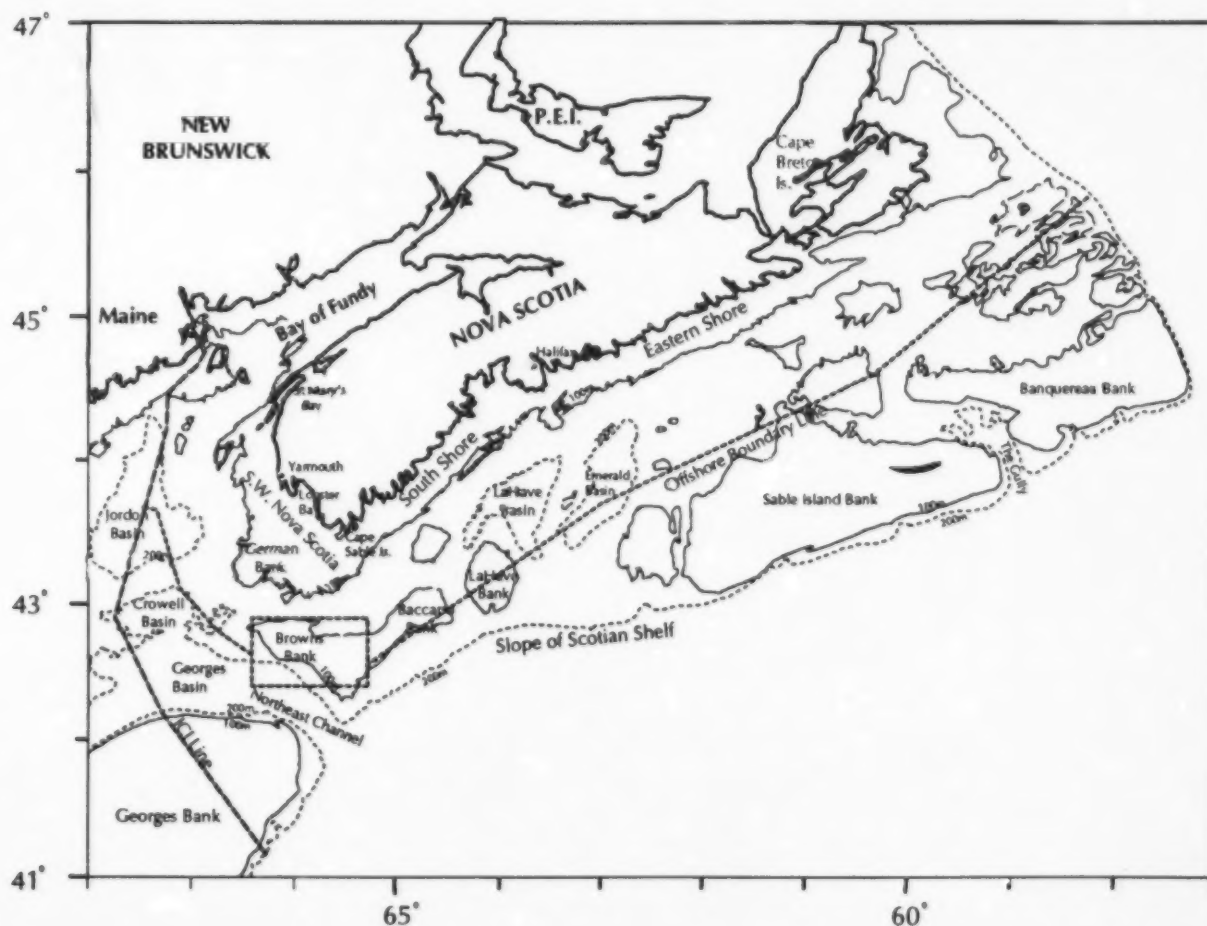


Figure 5. Scotian Shelf and eastern Gulf of Maine.

Scotia-Fundy Resource Allocation Branch (F. Scattolon, pers. comm.). These concerns are the topic of this report.

HYPOTHESES

HYPOTHESIS 1: WITHOUT THE OFFSHORE FISHERY SIGNIFICANTLY MORE LOBSTERS WOULD MOVE INSHORE AND BE TAKEN BY THE INSHORE FISHERY.

Evidence not supporting the hypothesis

Lobster movement - Extensive tagging of offshore lobsters (LFA 41), and those from the Browns Bank closed area (Fig. 1) show little movement of offshore lobsters to the inshore fishing grounds (Table 1). Studies with the largest numbers of tagged lobsters, and the highest tag return rates show negligible inshore movement (<1%; Table 1). The highest percentage of inshore tag returns (7%) was based on lobsters tagged in 1975 in the Browns Bank closed area (Campbell and Stasko 1985), though a larger study in 1984-85, with higher overall returns had low inshore returns (<1%). Multiple recaptures

of berried females in and around this area provide convincing evidence of homing and seasonal movements that are restricted to the offshore (Pezzack and Duggan 1986; Pezzack and Duggan, unpubl. data). A few lobsters tagged in Jordan Basin were recaptured by inshore vessels (approximately 6% of returns; Table 1). Most of Jordan Basin lies within American waters, with the Canadian portion split between offshore and inshore (LFA 34 and 38). The Canadian offshore portion of Jordan Basin is small and has never been fished by the Canadian offshore fleet (Pezzack and Duggan 1987), presumably because of low catch rates. Because most of Jordan Basin is in U. S. waters (Fig. 5) even if Canadian offshore effort increased in the Canadian part of the Basin, it is expected that the landings would comprise a small percentage of the total offshore landings.

The lack of offshore tag returns in inshore waters could be due to the lobsters being offshore during the inshore fishing season (late November to the end of May). However, returns from the Jordan Basin release, and the appearance of large berried females in nearshore catches during May suggest that at least some inward movement would be detected if it was significant.

Table 1. Summary of tagging studies in the Canadian offshore or in the Browns Bank closed area Browns Bank. Inshore returns are defined as the number of animals captured in the inshore LFA 33 and 34; % of total returns is in brackets

Tagging Date	Tagging location	N lobsters tagged	N returns (%)	Canadian Inshore returns N (%)	Reference
summer 1973	Browns B (closed area since 1979)	163	30 ¹ (18)	0	Campbell et al. 1984
summer 1972	slope near Baccaro B & Browns B	475	55 ¹ (12)	0	Campbell et al. 1984
summer 1972	Northeast Georges B	161	14 ¹ (9)	1 (7.1)	Campbell et al. 1984
April 1972	Corsair Canyon	70	6 (8)	0	Campbell et al. 1984
summer 1975	Browns B (closed area since 1979)	1293	198 (15)	13 (6.6)	Campbell & Stasko, 1985
July 1983	Crowell Basin	433	- 379 ² (38)	0	ANON, 1985
July 1983	Jordan Basin	569	-	12 (6.3) ³	ANON, 1985
1983-88	Browns B. (closed area since 1979)	8731	2255 (26)	13 (0.6)	Pezzack & Duggan unpubl. data ⁴
	Georges Bank	4894	1288 (26)	0	Pezzack & Duggan unpubl. data ⁴
	Scotian Shelf/Fundian Channel	7539	3545 (47)	5 (0.1)	Pezzack & Duggan unpubl. data ⁴
	Crowell Basin	1749	263 (15)	2 (0.7)	Pezzack & Duggan unpubl. data ⁴

1 N returned from release and recapture points (Figs. 4-7) in (Campbell et al. 1984).

2 Breakdown of lobsters into Jordan Basin and Crowell Basin not given.

3 Assumes half of total returns were of Jordan Basin lobsters.

4 Approximately 50% of tagged lobsters were ovigerous in Pezzack and Duggan studies.

Landings - Offshore landings over the last 5 yr. have averaged about 7% of the inshore landings in LFA's 33 and 34. Coupled with insignificant movement of offshore lobsters to the inshore, these low landings relative to the inshore indicate that the number of lobsters removed by the offshore fleet that would be available to the inshore fishery is small.

Near the inshore-offshore dividing line (50-65 nautical miles from shore), the two fleets are fishing side by side (Sharp and Duggan 1985), and presumably there is some movement of lobsters back and forth over the line. Within this limited area the inshore and offshore fleets are fishing the same lobsters, but the percentage of the total inshore landings taken in this area is thought to be small.

The lobsters near the line are closer to the offshore lobster concentrations (rather than those in the midshore). Inshore trap distribution in the spring (Sharp and Duggan 1985) and experimental trapping in the summer (Pezzack 1983) showed a discontinuity in effort and lobster distribution between the midshore and the offshore in the region north of Browns Bank.

Inconclusive evidence

School lobsters - Morphologically distinct "school lobsters" appear in the late spring nearshore fishery (between Yarmouth and Cape Sable Is.; Aiken 1971). These lobsters may be migrants from elsewhere, but their appearance could also reflect changes in catchability. There is no evidence that they originate from offshore (LFA 41). It seems more likely that such lobsters originate from the midshore region, although inshore movement of midshore lobsters has not been shown. Most lobsters tagged around the Middle Ground and German Bank areas were recaptured either close to the tagging site, or in the offshore (Campbell and Stasko 1985; Campbell 1989).

Size structure - The size structure of lobsters in the nearshore fishery differs greatly from that of offshore lobsters (Wilder 1974; Pezzack 1987). The length frequency distribution of offshore lobsters is characterized by modes of 105-130mm carapace length (CL), while the modal size of smaller inshore lobsters is near the minimum legal size of 81 mm CL (Pezzack 1987). The size structure of midshore lobsters overlaps that of both areas (Stasko and Pye

1980; A. Campbell, pers. comm.). Size frequency of the catch is dependent on the history of exploitation rates in the fishery and may be influenced by time of year and trap selectivity.

Conclusion

Hypothesis 1 was rejected based on tagging studies and a comparison of inshore and offshore landings.

HYPOTHESIS 2: WITHOUT THE OFFSHORE FISHERY SIGNIFICANTLY MORE OVIGEROUS FEMALES WOULD MOVE INSHORE DURING SUMMER AND RELEASE LARVAE

Evidence not supporting the hypothesis

Movement of ovigerous females - Tagging studies of offshore ovigerous lobsters indicate that they do not move inshore during the inshore fishing season (Table 1), but do move to shallower water on the offshore banks during summer. Multiple recaptures on the slope of Browns Bank show that ovigerous females undertake long-distance seasonal movements, but remain offshore (Pezzack and Duggan 1986; Pezzack and Duggan unpublished data).

Seasonal changes in the depth of fishing shows that there is shoalward movement of commercial size lobsters in the offshore during spring/summer (Fig. 6). Beginning in May, the offshore fleet moves its traps into shallower waters to follow this seasonal movement. Together with the multiple recaptures (see above), these data suggest that in summer, berried females in the Northeast Channel move to depths of 40-80 m within the Browns Bank closed area, and those on the Scotian Slope move up onto the edge of the Scotian Shelf (depths of 80-120 m). Lobsters along the outer slope of Georges Bank migrate to Georges Shoal (Pezzack and Duggan 1988; Uzmann *et al.* 1977). It is assumed that in these cases, larvae are released in the shallow areas of the banks.

Small effect of the offshore fishery on offshore lobsters - In case inshore movement of ovigerous females is underestimated, it is prudent to determine if the offshore fishery has affected the abundance, or size structure of offshore lobsters. If the abundance has declined, then the number of

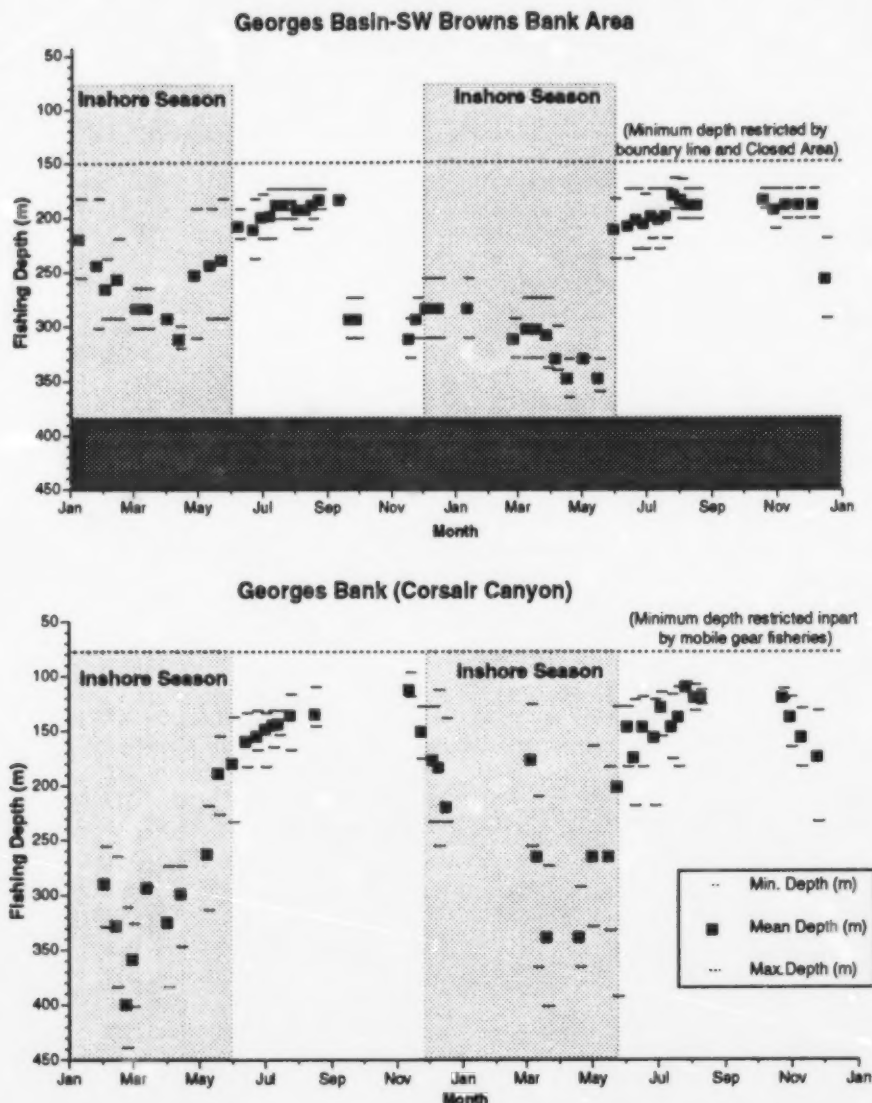


Figure 6. Fishing depths (Mean, Min. and Max.) per trip, by offshore vessels fishing Georges Basin-SW Browns area, and Corsair Canyon on Georges Bank (1983-4). Assuming fishing depth reflects distribution of lobsters, data shows offshore lobsters still in deep water during the inshore season and that larger lobsters observed late in the season inshore are not likely of offshore origin. Minimum depths determined in part by inshore/offshore lobster boundary line and mobile gear on the Banks.

ovigerous lobsters moving inshore would be reduced. Furthermore, if the offshore fishery has reduced the size of lobsters, then potential egg production would be reduced.

Catch per unit effort (CPUE) shows no long term trend over the 17 years of monitoring, which sug-

gests that the offshore fishery has had little effect on the density of offshore lobsters (Pezzack and Duggan 1988). In addition there is no evidence of a change in the offshore lobster size structure over that period. American experience in the offshore fishery of Southern Georges Bank showed that high exploitation can reduce the average size and shift the mode

from mature to immature sizes (Skud 1969). Data from the fishery on CPUE and size structure (Pezzack and Duggan 1987) must be interpreted with caution, due to fishing strategies and to trap selectivity. However it is thought that large changes in CPUE and size structure would likely be detected from these data.

Inconclusive evidence

Appearance of ovigerous females inshore - In many areas of the coast berried females comprise a larger percentage of the inshore catch in May (near the end of the fishing season) than during the rest of the season (Campbell and Pezzack 1986). If migrants, these lobsters are likely to have arrived from deeper waters in the midshore (rather than the offshore) but such movement has not been demonstrated (see evidence not supporting Hypothesis 1). It is also possible that the appearance of ovigerous females (like "school lobsters") results from a change in their catchability. If ovigerous females were able to migrate to the coast, release larvae and then return offshore between June and December, such movement would not be detected. However tagging of ovigerous females in the offshore (where the fishery is year round), and inferences regarding movement based on seasonal changes in catch rate, indicate that significant numbers of offshore ovigerous females do not move to the coast to release larvae.

Conclusion

We cannot reject Hypothesis 2, but the evidence at hand suggests that the offshore fishery is unlikely to reduce significantly the number of ovigerous females moving inshore to release larvae during summer.

HYPOTHESIS 3: LARVAE DRIFT FROM OFFSHORE TO SEED INSHORE GROUNDS

The inshore and offshore areas can be subdivided into regions in which lobsters occur, and from which larvae are likely to originate.

Browns Bank:

Browns Bank and the other areas in the Browns Bank Closed Area (LFA 40) were closed to all lobster fishing in 1979. Prior to that the area was divided between the inshore and offshore fisheries (Fig. 3).

The closure was designed to protect brood stock found on the bank. The presence of this brood stock make this an area of prime concern. The lobster fishery in the deeper water east and west of Browns Bank (Figure 4) accounts for most the Canadian offshore landings (Pezzack and Duggan 1988).

Georges Bank:

Georges Bank supports a large American and Canadian lobster fishery, centered in the canyons along the outer slope. Tagging studies have shown that a seasonal migration from the slope area to the shallower central bank occurs in summer (Pezzack and Duggan 1987; Uzmann *et al.* 1977), and it is believed that most larval hatching takes place on the bank.

Outer Eastern Scotian Shelf:

Lobsters exist along the outer Scotian Shelf as far east as The Gully (Pezzack 1984; Pezzack 1987), though apparently in lower numbers than in the Browns and Georges Bank areas. Lobsters are not found in the basins between the shelf edge and the coast (Fig. 4). The lack of lobsters over most of the shelf means that any larvae produced offshore would have to be transported from the shelf edge to contribute to inshore populations.

Each of these areas is very large and is characterized by different oceanographic features. For the discussion of the inshore-offshore interactions they were divided into four potential linkages:

1. Browns Bank (Closure area) to Southwestern Nova Scotia (LFA 34);
2. Georges Bank (LFA 41) to Southwestern Nova Scotia (LFA 34);
3. Browns Bank (Closure area) to South Shore Nova Scotia (LFA 33);
4. Eastern Scotian Shelf to South Shore Nova Scotia (LFA 33).

drifters and not actual larval drift measurements. As a result, the exchange has been modeled on the assumption that larvae are solely subject to passive transport (Harding and Trites 1988). However, results from many studies dealing with other species suggest that the effect of larval behaviour (directional swimming and vertical migration) on their spatial distribution cannot be neglected (Campana *et al.* 1989; Harding *et al.* 1987; Iles and Sinclair 1982; Page and Smith 1989; Sinclair 1988; Smith and Morse 1985; Weinstien 1988).

Conclusions

The physical evidence and larval distribution data are equivocal. An oceanographic mechanism exists for larvae to drift from Browns Bank to German Bank and to nearshore areas north of Yarmouth and to the Cape Sable Island area. There is also a mechanism for larvae to drift from Browns to the inshore area between Cape Sable and Yarmouth, but this mechanism is dependent upon a lobster behavior pattern that has not been observed.

2. GEORGES BANK TO SOUTHWESTERN NOVA SCOTIA

Evidence not supporting the hypothesis

Retention by Georges Bank gyre - Georges Bank has a strong clockwise gyre with high retention (Bumpus 1976; Colton and Anderson 1983; Perry and Hurley 1986; Smith and Morse 1985). Residence time over the shallow central Bank can be 2 months (Loder *et al.* 1988), more than enough time for larval development. (Butman *et al.* 1982; Loder *et al.* 1982). Oceanographic data suggest that water exchange from Georges Bank to nearshore areas may be low.

Inconclusive Evidence

Distribution of zooplankton and larvae - Studies of the distribution of zooplankton, (chaetognaths: Lough and Bolz 1989), molluscan larvae (scallop: Tremblay and Sinclair 1992) and ichthyoplankton (cod and haddock larvae: Colton and Anderson 1983; Lough and Trites 1989; Smith and Morse 1985) over Georges Bank suggested that most larvae were successfully retained on the bank during their development. However recent studies (Perry *et al.* 1992; Harding unpubl. data) show that some zoop-

lankton species, and lobster larvae are present off the northern edge of Georges Bank. These larvae may have originated on the bank, or possibly upstream (i.e. Great South Channel). The lack of a systematic survey of the entire bank makes it impossible to estimate the proportion of production lost through this mechanism.

Larvae lost from the northern edge would likely be retained in the Gulf of Maine, and settle in the deep basins or be transported into the Bay of Fundy (Bumpus 1960; Perry and Hurley 1986), but could return to Georges Bank or exit to the North Atlantic via the Northeast Channel (Brooks 1985). Lawrence and Trites (1983) modeled the dispersion of an oil slick from a point on eastern Georges Bank. In 2 of 3 trials the slick reached southwest Nova Scotia within 40 days, assuming wind induced drift speed typical of the top few centimeters. The range of potential larval drift is dependent on how drift speed is calculated. If a slower drift speed typical of subsurface depths (Smith 1989) is used larvae would settle offshore in the deep basins. However using the surface drift speeds given in Harding and Trites (1988) larvae could drift to nearshore areas.

Conclusions

The potential for significant larval drift from Georges Bank to inshore Southwestern Nova Scotia appears to be small.

3. BROWNS BANK TO SOUTH SHORE OF NOVA SCOTIA

Inconclusive evidence

Surface drifters - Surface drifters released on and near Browns Bank were usually recovered in the Gulf of Maine or Bay of Fundy, but exceptions do occur. Satellite tracked drifters released on Browns in the summer either remained on Browns or drifted toward the Gulf of Maine (Smith 1989). Over 95% of recovered drift cards and bottles released by Harding and Trites (1988) on and near Browns were recovered from the Gulf of Maine; a few recoveries from one of three releases were from near Cape Sable Island. Drift bottles were released between Cape Sable Island and Baccaro Bank on seven occasions between July and October, 1922-1926 (Trites unpubl.). Releases on Baccaro traveled towards the

Bay of Fundy or east to the offshore, but many released shoreward of the bank were recovered on the South Shore as far as 100 km east of Cape Sable Island. A release on Browns in June, 1954 resulted in a few recoveries near Cape Sable Island (Trites 1979).

Nova Scotia Current - A dominant oceanographic feature is the Nova Scotia Current which flows southwest along the inner Scotian Shelf. On the outer coast it is centered along the 150 m depth contour, 25-50 km from shore. This current is weakest (Drinkwater *et al.* 1979; Smith 1983) and may even reverse direction in summer (Trites 1979). As a result, wind forcing may exert a stronger influence on larval drift than residual flow. Surface drifters would be most susceptible to wind during summer.

Larval Distribution - A plume of post larval stage lobsters was observed about 70km off the South Shore of Nova Scotia (Watson and Miller 1991). Although coastal origin cannot be ruled out, it could have originated from Browns Bank (Watson and Miller 1991). It was not possible to determine whether the larvae settled in nearshore waters or not. The center of the larval concentration was well off the coast with little or no larvae near the coast, though no samples were taken in the immediate coastal areas. A different wind direction could conceivably have carried the larvae inshore. Once settled, lobsters are thought to move little until they reach sexual maturity several years later (Miller *et al.* 1989 for review).

Conclusions

The potential exists for larvae to drift from Browns Bank to nearshore areas of the South Shore, with a decreasing probability east of Cape Sable Island. Because a particular set of intermittent current and wind conditions are required for drift from Browns Bank to the South Shore, such contributions are likely to be sporadic.

4. EASTERN SCOTIAN SHELF TO SOUTH SHORE OF NOVA SCOTIA

Evidence not supporting the hypothesis

Drifter data - Data presented by Trites (1979) showed that surface water movements along the

south and east coasts of Nova Scotia have an offshore component.

Larval distribution - Analysis of SSIP data showed no larvae between the offshore Banks east of Browns and the coast (Stasko 1977; Watson and Miller 1991). There was no clear indication of drift from the offshore Banks to the coast.

Larval drift - It is possible that a passively drifting larvae from west of LaHave Bank could drift along the shelf edge to Browns Bank, to the Northeast Channel, and then inshore (R. Trites pers. comm.). However it is not known how long it would take for lobster larvae to drift inshore from the shelf edge.

Conclusions

Contribution of larvae from the outer eastern Scotian Shelf to the inshore areas is considered to have a low probability of occurrence.

GENERAL CONCLUSIONS ABOUT LARVAL DRIFT FROM OFFSHORE TO INSHORE

No clear consensus was reached at the workshop. Inflow of offshore larvae to the inshore areas is possible for any area of the coast, but the quantity and viability of the larvae are unknown. In nearshore regions, where local larval production is high, such contributions may be much lower than local recruitment and thus have little numerical significance. The importance of outside larval contribution is also dependent on the relationship between larval numbers and recruitment to the fishery. There is no measurable relationship between egg production and subsequent recruitment to the fishery. A lack of a relationship between larval numbers and recruitment would make the question of offshore contributions academic.

The most likely offshore source for Southwestern Nova Scotia and the South Shore would be Browns Bank. Browns Bank larvae could be transported to the nearshore areas north of Yarmouth or towards Cape Sable Island, but the only mechanism suggested for transport of larvae to the highly productive nearshore lobster grounds between Cape Sable Island and Yarmouth involved a type of lobster behavior that has not been observed. The chance of

drift from Browns Bank to the South Shore decreases with increasing distance east of Cape Sable Island and the physical processes necessary for transport are intermittent.

HYPOTHESIS 4: THE OFFSHORE FISHERY SIGNIFICANTLY REDUCES THE LARVAL PRODUCTION THAT DRIFTS INSHORE

Evidence not supporting the hypothesis

Size structure - Since the beginning of offshore exploitation, no change in the size structure of the Canadian offshore catch has been observed on an area-by-area basis (Pezzack and Duggan 1985; Pezzack and Duggan 1988). Size frequency distributions are dominated by mature sizes, which suggest that offshore fishing mortality is low (Campbell and Pezzack 1986; Pezzack 1990), thus inducing negligible effects on brood stock abundance. Thus larval production in the offshore appears to have been unaffected by the offshore fishery. However, it is possible that traps might not be sensitive in detecting a short term temporal change in lobster size structure. The grounds fished and the trap ring size have shifted over time, and for marketing reasons the fishery now targets areas that have always had smaller sized animals (thus presumably resulting in a lesser mortality of very large animals).

Median size of females - Since the median size of females captured offshore (>105 mm CL, (Campbell and Pezzack 1986) is larger than the median size at maturity (95 mm CL, (Campbell and Robinson 1983; Pezzack and Duggan 1989) most offshore females could reproduce once or twice before capture.

Inconclusive evidence

CPUE - Yearly CPUE (kg/trap haul) has increased inshore during the 1980s (Anonymous 1989) but has shown no consistent trend offshore during the 1970-80s (Pezzack and Duggan 1985; Pezzack and Duggan 1988). However the offshore fishery takes place during the migratory period, and CPUE are affected by the timing, distribution and cohesiveness of the lobster migration. CPUE is also affected by changes in fishing strategy and efficiency

Decrease in mean size on southern Georges Bank - A decrease in mean size following heavy exploitation by a trawl based fishery was reported by

Skud (1969) for southern Georges Bank, though there was no subsequent decline in either inshore or offshore landings.

Closure Area - An unknown proportion of the offshore brood stock, located inside the closure area of Browns Bank, is protected from the lobster fishery. But a portion of the lobsters migrate in and out of the closure area on a seasonal basis, making them periodically vulnerable to the fishery.

Conclusions

It does not appear that the present offshore fishery is having a measurable effect on the offshore size structure which would reduce the potential larval production.

HYPOTHESIS 5: LARVAL PRODUCTION INSHORE IS SUFFICIENT TO SUSTAIN INSHORE POPULATIONS

Inconclusive evidence

Egg production - Estimates of egg production calculated from the size frequency histograms of mature females captured inshore and offshore also differed among studies (Campbell and Pezzack 1986; Harding and Trites 1988; Harding and Trites 1989; Pezzack 1989). Discrepancies in the estimated contribution were based on the assumptions used, such as the probability of imports of larvae from Georges Bank, the selected median size of females in each region, the minimum size at maturity, and the percentage of females in the population. Estimation of inshore egg production suggests that egg production inshore is equivalent or greater than that found offshore (Campbell and Pezzack 1986; Pezzack 1989).

Larval production - Comparisons of inshore and offshore larval production depend on the definitions used for each area. Using the larval concentrations reported in Stasko and Gordon (1983) and defining offshore waters as deeper than the 20 m isobath, Harding and Trites (1988) calculated that larval production offshore was one order of magnitude larger than inshore. The 20 m contour is an extremely restrictive definition of inshore. A more realistic definition would correspond to Stasko and Gordon (1983) "Offshore North" plus the areas <20 m. Use of this definition reduces the importance of the offshore (Browns Bank; Pezzack 1989).

Post Larval Stage production - Inshore post larval stage production calculated for southwest Nova Scotia is in the same order of magnitude as western Northumberland Strait (Harding *et al.* 1983). However, it is not known if those post larval stages captured inshore are produced locally or imported from offshore. An area-by-area comparison using stage I would be preferable, although such data are not available.

Conclusions

The number of eggs (or larvae) deemed "sufficient" to sustain the present level of fishery remains to be determined. Data are insufficient to evaluate this hypothesis.

HYPOTHESIS 6: LARVAE RELEASED IN-SHORE SETTLE INSHORE

Little work has been done on larval distribution in inshore waters of Nova Scotia (Di Bacco and Pringle 1991; Stasko and Gordon 1983; Tremblay and Sharp 1989), and nothing on possible drift or displacement to the offshore. Few studies have been done on coastal circulation of south and southwestern shores of Nova Scotia (Platt *et al.* 1972; Sharaf el Din *et al.* 1970; Weinstien 1988)

Evidence not supporting the hypothesis

South shore Nova Scotia Displacement of coastal water - There can be fast displacement of water masses in inlets along the coast of Nova Scotia (Heath 1973; Petrie *et al.* 1987; Platt *et al.* 1972). Offshore winds can abruptly displace surface waters from the coastal bays, while the reverse occurs with an onshore wind.

Evidence supporting the hypothesis

Southwestern Nova Scotia Front as potential barrier to exchange - There appears to be a relatively isolated "inshore" water mass inside the 100 m isobath between Cape Sable Island and Yarmouth (Smith 1989). Drifters released on Browns generally escape from the northwestern edge of the Bank but remained along the 100 m isobath off German Bank, and seldom moved inshore of the 50 m isobath. Therefore, a passive larva released within the 50-100 m isobath contour off German Bank

would drift northerly within the coastal current rather than being advected offshore (Smith 1989). Depending on the location of larval release relative to the front (which also presumably moves with time), larvae may settle on German Bank, be retained nearshore, or be deflected northwards to Lurcher Shoal, the coast North of Yarmouth, or the Bay of Fundy.

Inconclusive evidence

Southwestern Nova Scotia Retention mechanism in Lobster Bay - There is no evidence of a surface retention mechanism in Lobster Bay to retain local larval production. However, although the upwelling occurring in Lobster Bay transports water away from the coast (Garrett and Loucks 1976), there have been no studies of water movements in the immediate coastal areas or in the many inlets and around the islands.

South shore Nova Scotia Flushing of lobster larvae from embayments - The flushing of lobster larvae from embayments and coastal areas could result in their general transport downstream along the coast of Nova Scotia (i.e. southwestward) or advection offshore as a response to wind-driven Ekman circulation. (P. Smith, R. Trites pers. comm.). Only Stage I larvae were captured in a weekly larval survey (Di Bacco and Pringle 1991) between July 21 and September 22, 1988 in Jeddore Bay (eastern shore). The absence of later stage planktonic larvae could be attributable to the high flushing rate of the bay, evaluated as 4-5 tidal cycles, or approximately 2-3 days. Drift bottles suggest that the probability of loss offshore increases as one moves east from Cape Sable Island.

South shore Nova Scotia Warm core eddies - Periodic displacement of water occurs between the coast and the offshore when warm core eddies impinge on the shelf edge. Although these occur at irregular intervals, they have the potential of removing large volumes of coastal water (Smith and Sandstrom 1988).

Conclusions

Along Southwestern Nova Scotia, there is a potential larval loss from the immediate nearshore areas to midshore areas or to other inshore areas

(north of Yarmouth and the Bay of Fundy). The extent of such loss is unknown.

The potential for losses are greater along the South Shore, where offshore displacement of water occurs regularly. Some of this water may be displaced southward and eventually returned to the nearshore areas, but advection offshore and off the Scotian Shelf are also possible. The probability of loss to the offshore increases as one moves northeast up the coast.

GENERAL CONCLUSIONS

This document points out many uncertainties that remain regarding the interactions among nearshore, midshore and offshore lobster aggregations. Nevertheless, the authors feel that there is sufficient data at hand to draw some conclusions about the effect of the offshore fishery on the lobster catch by the inshore fishery (where "inshore" includes both nearshore and midshore). These are as follows:

- 1) A stable size frequency and the lack of trend in CPUE throughout the history of the offshore fishery suggest that the fishery has had no more than a small impact on population structure and size. Thus, even in instances of offshore-inshore interchange, any influence of the offshore fishery has probably been small. However, the fishery may in the future affect population dynamics offshore and the mechanisms of possible interaction with the inshore are considered.
- 2) Tagging results show that the number of lobsters moving from the offshore to be taken by the inshore fishery would be negligible with or without an offshore fishery.
- 3) Although less certain, and deserving more study, offshore tagging suggests that movement of offshore ovigerous females to the inshore area to release larvae in summer is unlikely.
- 4) If larvae are transported by surface drift, those released on Browns Bank may settle on the midshore along the 100 m contour or in nearshore areas north of Yarmouth, and near Cape Sable Island, but not in the productive nearshore

grounds between Yarmouth and Cape Sable Island. Larval drift from Browns Bank up the South Shore at least as far east as Liverpool may occur, but with a frequency depending on wind speed, direction, and duration. The Browns Bank closed area provides a partial refuge for the females releasing these larvae.

- 5) Currents and the duration of larval stages would limit significant larval transport from Georges Bank or the eastern Scotian Shelf (NAFO district 4W) to inshore.
- 6) If larval production and settlement inshore is sufficient to sustain the population(s), offshore contributions would be irrelevant. Even in cases where the offshore contributes larvae to the inshore, inshore production may be essential to maintain inshore populations. However, neither the required nor the available inshore production is known.
- 7) The authors believe that our understanding of the relationship between the inshore and offshore can be improved and recommendations for future research are discussed in this paper. It is recognized that the design of studies to resolve the uncertainties and quantify interactions will be challenging. Under consideration are over 100,000 km² of ocean with a complex and variable physical environment, and a biological system influenced by both the environment and intense fisheries.

ADVICE TO MANAGERS

We suggest that the offshore fishery has not affected the inshore fishery thus far. If it has a potential for negative impact it would be through the reduction of larval production near Browns Bank. Removing lobsters from Georges Bank, or the eastern Scotian Shelf is unlikely to affect the inshore fishery.

A larger impact on the nearshore fishery may result from the increased fishing effort in the midshore area, an area largely unfished until the late 1970s.

RESEARCH TOPICS

It was the opinion of the workshop participants that future research should focus on a multi-disciplinary program to understand the dynamics of the inshore Southwestern Nova Scotia system, specifically the Lobster Bay area. The inshore areas represent the vast majority of the lobster population and an understanding of the dynamics within this area is necessary before it can be determined if outside contribution is needed or occurs. Biological investigations should centre on attempting to quantify inshore production and settlement to determine if the inshore population is self sustaining. Work is needed to understand the environmental and ecological factors that determine abundance and at what stage of the life history is recruitment determined. Physical oceanography should center on local circulation patterns and relationship to offshore and other nearshore areas. Knowledge of circulation is essential to resolve the questions of retention and input from other areas. Such work may be relevant to other issues and species and would be best approached by an integrated multi-disciplinary program.

Individual studies that could be carried out in such a program are listed below.

OCEANOGRAPHY STUDIES

Inshore oceanographic work would obtain information on water movements, flushing rates and temperatures that are central to the understanding of how the physical environment affects larval recruitment dynamics in the inshore area.

- 1) Study of the coastal upwelling and frontal system off Southwestern Nova Scotia to determine retention and displacement potential.
- 2) Study of coastal flushing and water retention in bays, with particular interest in Lobster Bay.
- 3) Develop a circulation model that would allow prediction of larval transport, while taking into account the larval vertical distribution.

LARVAL STUDIES

A knowledge of water movements alone cannot describe the movements of larvae and studies would be required to determine this. Offshore larval work has been successful in studying vertical distribution of larvae and similar work would be needed in the inshore area.

- 1) Develop sampling methods for nearshore areas and conduct inshore larval studies to determine distribution and production levels relative to oceanographic and coastal features.
- 2) Investigate development of a natural tag (colour, genetic, morphometric) that would allow the identification of the origin of larvae.

JUVENILE STUDIES

Juvenile studies would supply information on the critical period between larval settlement and entry into the fishery. There is presently little known about this life history stage. The studies would aim at determining the earliest stage at which there is a relationship between juvenile numbers and recruitment to the fishery.

- 1) Develop a post-larval collector to provide an index of yearly settlement, and monitor yearly prerecruit abundance through trap surveys to establish a correspondence between settlement and subsequent landings.
- 2) Characterize and map "nursery" areas in Lobster Bay and selected offshore areas to evaluate potential production of recruits and flag areas which may require habitat protection.
- 3) Determine variability in individual growth under natural conditions and assess its effect on survival and recruitment to the fishery.

ADULT STUDIES

The adult stage is critical to an understanding of the dynamics of the system. It is during the adult stage that migrations occur which determine the locations of egg hatching, and the availability of animals to the nearshore, midshore and offshore fisheries.

- 1) Determine origins of larger and berried lobsters that appear in traps inshore during the spring and summer. Determine if these are local lobsters being caught due to a change in catchability or migrants from the midshore or offshore.
- 2) Determine inshore distribution and abundance of berried females during early summer to determine hatching locations and larval production.
- 3) Determine the effect of trap selectivity on the size frequency of offshore catches to establish if the captures truly reflect the population size structure.

LOBSTER POPULATION AND PRODUCTION MODEL

Development of a lobster production model would draw together existing information and aid in planning future work. It would allow researchers to test hypotheses concerning changes and variations in growth, survival, and fishing at the different life history stages. Work on this model should be coordinated with a similar model being discussed by American researchers.

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